WCRP REPORT

World Climate Research Programme

Climate Observations and Regional Modeling in Support of Climate Risk Management and Sustainable Development[1]

Consolidated Country Reports

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Introduction

A series of three workshops on "Climate Observations and Regional Modeling in Support of Climate Risk Management and Sustainable Development" for the Greater Horn of Africa countries was implemented to demonstrate key elements of an effective climate risk management strategy for the region. The World Climate Research Programme, the Global Climate Observing System, the World Meteorological Organization and the Nairobi-based IGAD[2] Climate Prediction and Applications Center (ICPAC) joined together to implement this project funded by the World Bank (WB) Global Facility for Disaster Reduction and Recovery (GFDRR).

The first workshop explored changes in climate indices of temperature and precipitation extremes, derived from available observed data over the GHA region. It was held on 19-23 April 2010 in Nairobi, Kenya. The second workshop, also held in Nairobi, Kenya, on 21-25 February 2011, accessed how realistically the current climate is simulated using high resolution Regional Climate Models (RCM) and thereafter investigating the uncertainty associated with constructing climate scenarios. The outcomes of the first two workshops were examined and their usefulness in the development of effective adaptation strategies assessed, in the third workshop (Arusha, Tanzania on 1-4 March 2011) that involved scientists, users and policy makers. This document is the consolidation of the Country Reports that were presented by the participants at Workshop 3 in Arusha, with additional material provided through ICPAC. They are organized by order of presentation.

In Workshop 1, the participants brought their national data sets which they quality-controlled using the procedures presented at the workshop and then calculated selected climate indices[3] based on the needs that they determined to be most relevant to their country in light of the available data and the climate conditions. Annex 1 provides a list of the 27 climate indices developed by the WMO/WCRP/IOC *Expert Team on Climate Change Detection and Indices* (ETCCDI).

Workshop 2 focused on regional modeling, using the PRECIS regional model from the UK MetOffice. Participants accessed the model simulations by comparing the current climate indices from the model with those from the first workshop. They also investigated PRECIS projections of climate conditions to 2050 for use in adaptation and risk analyses. This provided the participants with hands-on training in the analysis of observational data and model output for future use in their countries. Participants became aware of both the benefits and limitations in using and interpreting regional model simulations in climate applications. Examples of their analyses are given in this report.

Workshop 3 emphasized ways to make climate information more useful for policy, economic and humanitarian decisions and actions. The workshop sought ways to integrate climate information into decision tools and decision making processes, develop adaptation strategies for the agriculture and water sectors, and link disaster risk reduction and climate change. The participants also benefited from attending the 27th session of the Greater Horn of Africa Climate Outlook Forum (GHACOF), which presented the current climate outlook and reviewed past experience with seasonal climate outlooks in the GHA region. This provided a most appropriate and informative introduction to the third GFDRR workshop due to the past success of the GHACOF process in producing and using seasonal climate information in agriculture, water resources, and other sectors to benefit the people of the GHA region.

The country analyses in this report and the Workshop 1 Report are the initial steps in developing national capabilities to use both national and regional data together with downscaled regional model output in national and regional analyses of changing climate conditions.

[2] IGAD is the Inter-Governmental Authority on Development in eastern Africa.

At the conclusion of each Workshop, participants were asked to prepared "country reports" summarizing their results. Representatives from each country made a final presentation at workshop 3 summarizing their work over the entire project. They were also asked to address the following questions:

1. What type of extreme events does your country experience?
2. What is the evidence of climate change in your country?
3. How adequate are climate change models for your country?
4. What adaptation strategies do you recommend for your country based on the climate model projections, in addition to any ongoing activities?

What are the main limitations you anticipate in the implementation of the adaptation and mitigation that you have recommended for your country?

1. Sudan

Presented by Mr. Badr Eldin Mamoun

Introduction

Sudan has 5 climatic zones – arid, semi-arid, poor Savannah, wooded Savannah and equatorial – from north to south with data from 22 stations within these 5 zones. As a result, there are variations in the daily records of temperatures and precipitation.

Sudan benefits from having three rainfall seasons: (MAM) starting, (JJAS) peak, and (SOND) retreating season. The onset of the rainy season in the southern part of Sudan is March, while it begins in July in the extreme north. The impact of the climatic events in Sudan is more severe in Sudan, since a substantial proportion of the population is living on subsistence agriculture and hence is very vulnerable decreases in rainfall that lead to crop failure.

The Sudan Meteorological Authority (SMA) has made seasonal rainfall forecasts since 1999 that are disseminated at national and state levels. Since they have shown high accuracy, the Sudan government utilizes these forecasts in strategic planning for the different sectors in the country, especially for agriculture, livestock, and irrigation and with the public sector and Sudanese Farmers' Union. This has allowed the SMA to be an effective member on the council dealing with crisis and disaster management.

Methodology

Most stations have daily records of precipitation, maximum and minimum temperature in the period from 1961-1999. These records were put the correct format for the Rclimdex software and tests were performed for homogeneity using the mass curves. This data was then subjected to statistical quality control and missing values were filled using Climlab software by median for all stations. Finally the Rclimdex1.0 software package was used to calculate the indices from daily data from each station with particular attention placed on those indices that reflected climate extremes.

This report will focus on three climatic indices from five stations:

- Total annual precipitation (PRCPTOT),
- Number of cold nights where the temperature was less than the 10^{th} percentile (TN10p);
- Number of warm daytimes, where the temperature was greater than the 90th percentile (TX90p).

The five stations, one from each climatic zone, are at Khartoum, Abu Hamed, El Gadarif, El Fasher, and Juba. Then Sudan extracted PRECIS data for input to impact models, using the software Rclimdex to calculate climatic indices, from time series of daily precipitation, Tmax and Tmin from the model. They compared the model outputs with the observations, including mean annual cycles, to understand how well the model output compares with the observations, as one measure of assessing the quality of the model. They further

The statistics of the both observed and model data time series for the stations were obtained using the Trend statistical application software. Both the observed and model data were compared and plotted on the same axes.

Conclusions

From this analysis, the overall conclusions were that:

- Total annual rainfall (PRCPTOT) showed a decreasing trend for many of the stations except for the Khartoum station. Generally, consecutive wet days (CWD) showed a decreasing trend while the consecutive dry days (CDD) showed an increasing trend.

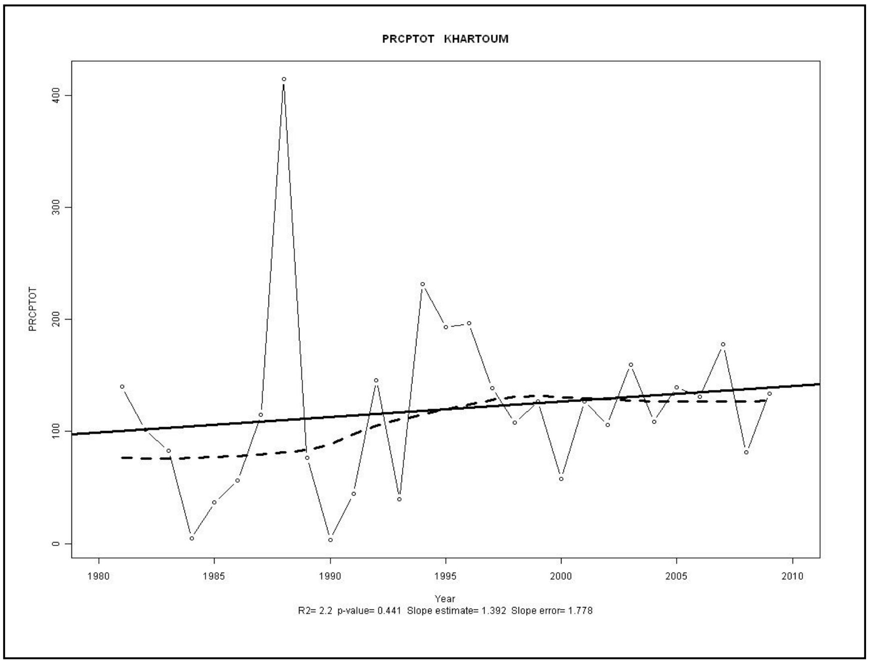
- While temperature indices vary from station to station, the dominant features seem to be an increasing trend in the number of cold nights (TN10p) with a decreasing trend in the number of warm nights (TN90p);
- The number of warm days (TX90p) has been increasing steadily since 1961, while there is a decreasing trend in cold days (TX10p).

For annual precipitation, the observed data were similar to the model output; in a few instances, the observed data were decreasing, while the model output was increasing. This difference may be due most likely to some circumstances where there were very heavy rains, e.g., over 200 mm in August in Khartoum in 1988 or in semi desert areas or both. In conclusion Mr. Mamoun noted that the sharp decline in the observed and the model data, especially in the recent years, indicate that the changes in the climate are getting more dramatic.

Results by Station

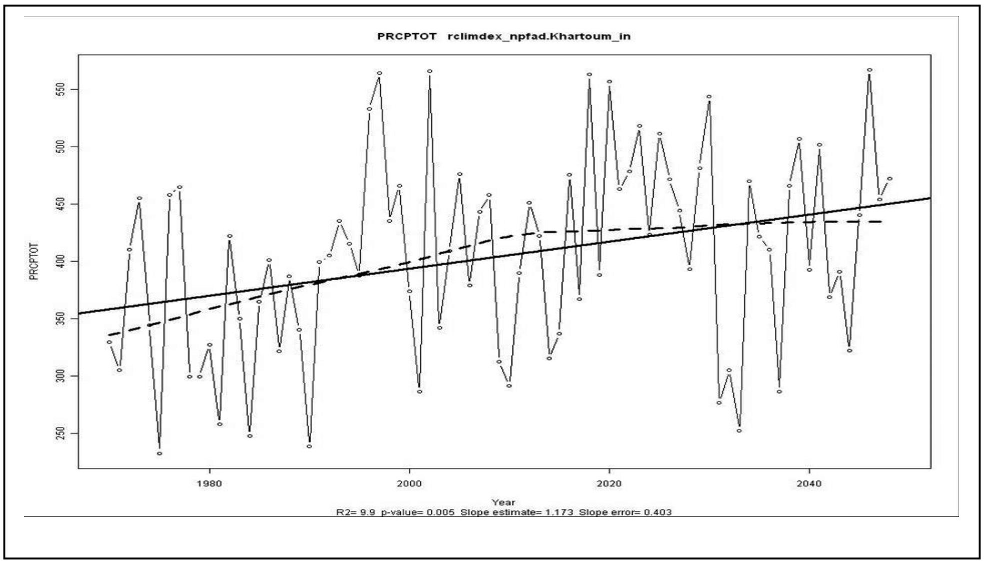
1) Khartoum

a) PRCPTOT – The annual total observed precipitation index for daily basis data period 1961to 2000 ,showed a decreasing trend, but started to decline from 1970-1985, started to rise gradually after that and reached the highest (reported 200mm).However, the model showed increasing precipitation from 1971 -2000.
b) Tn10p – The number of cool nights was observed decreasing steadily from 1960 -2000; the model showed a more severe decline over the same period.
c) Tx90p – The warm days were observed increasing, however, the model also confirmed increasing warm days.



Total Precipitation at Khartoum Station from 1980 to 2009[4]

[4]Solid line shows trends computed by linear least square and the dashed line is calculated locally weighted linear regression. Statistics of the linear trend fitting are displayed on the plots. This will be the same for all subsequent plots.



Total Annual Precipitation from PRECIS at Khartoum Station from 1970 to 2050

2) Abu Hamed

a) PRCPTOT – The observed annual total precipitation was decreasing but slight from 1961-2000.The model showed increasing precipitations.

b) Tn10p – The observed cool nights were increasing while the model showed them decreasing

c) Tx90p – The warm days observed increasing sharply for the period 1961-2000, while the model also confirmed the similar findings.

3) El Gaderif

a) PRCPTOT – The annual total rain was observed slightly, but steadily from 1961-2000 and the model output was increasing trend.

b) Tn10p – The cool nights were observed decreasing .The model also showed decreasing trend but sharply.

c) Tx90p – The warm days were observed increasing steadily and the model also showed increasing warm days

4) El Fasher

a) PRCPTOT – The annual total precipitation was observed decreasingly since 1961-2000, while the model showed increasing rains.

b) Tn10p – The cool nights were observed decreasing, while the model also showed decreasing cool nights.

c) Tx90p – The warm days were observed increasing and the model showed sharp increasing

5) Juba

a) PRCPTOT – The observed total annual precipitation, were found almost steady, while the model showed slight decreasing.
b) Tn10p – The cool nights were observed decreasing sharply, while the model showed similar decline.
c) Tx90p – The warm days were observed increasing while the model showed the increase

2. Kenya

Report prepared by M. Kalavi, S. M. King'uyu, and E. Muigai

Introduction

On behalf of the Kenya participants, Ms. Kalavi presented an oral summary at Workshop 3 focusing on the lessons learned from the analyses at WS2. She gave examples of climate change in Kenya, e.g., Mt Kenya glacier retreat, but opined that there were limits on the ability to adapt to potential impacts of climate change in Kenya due to low education and limited awareness of climate in many regions of Kenya, the need to translate climate change understanding and actions into a number of languages, resource constraints, and a resistance to change.

Methodology

Kenya used a standard approach to its analyses that used:

- Statistical analysis software for quality control and testing for homogeneity, prior to use in Rclimdex
- Rclimdex to calculate climate indices and to analyze trend in the regional models.
- PRECIS model to downscale GCM projections to regional scale for climate change impact studies. PRECIS output was then used in the Rclimdex to generate indices to compare with those from the national data;
- Trend analysis tool kit to analyze the significance of the trends.
- Arcview GIS software for effective visualization of results.

With regard to regional models, she note that while useful, regional models must be examined carefully, including model errors and other uncertainties before applying them to adaptation analyses. Models are always approximations of reality. Thus their uncertainties are propagated from the GCMs to the regional models to the analyses and can yield a significant error in making conclusions. She raised several issues, including:

- Difficulty in ascertaining the adequacy of a model with only a few stations for validation;
- Importance of working with users to define relevant thresholds of impact, e.g., for Tmax;
- Model simulations were quite good for temperature indices, indicating that the temperature projections may be useful for planning and policy formulation purposes;
- Need for additional indices (e.g., on wind speed) be defined for Rclimdex;

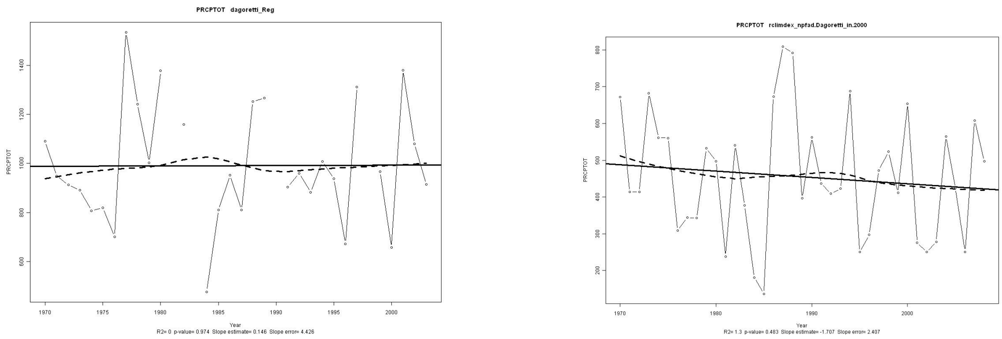
With regard to the workshops she stated that there was a need for additional time at WS1 & 2 for full analysis of the data, indices and model output; for software be made available prior to the workshops; and for the use of other regional models in addition to PRECIS.

Summary

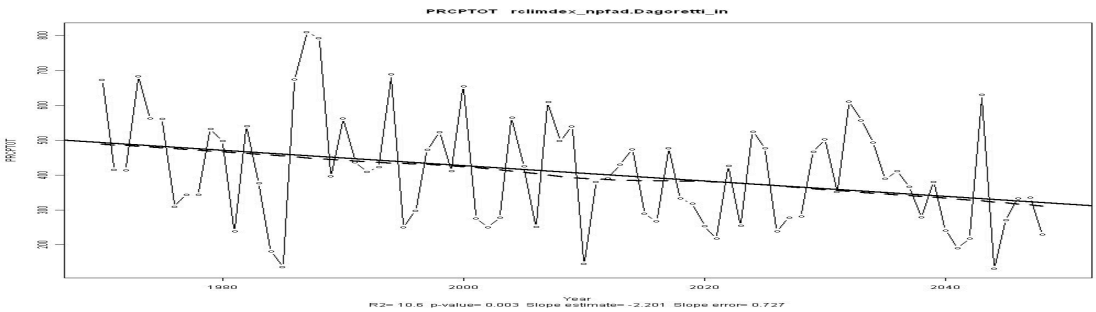
Model simulates the temperature indices quite well for all the stations and hence the model projections may be used for planning and policy formulation purposes and would be a useful tool for decision support systems (DSS). It could also be used for setting up early warning systems for extreme weather conditions. None of the precipitation trends were found to be significant but the model projections show a general decreasing trend.

Results from the analysis of the stations at Dagoreti and Lodwar are given below.

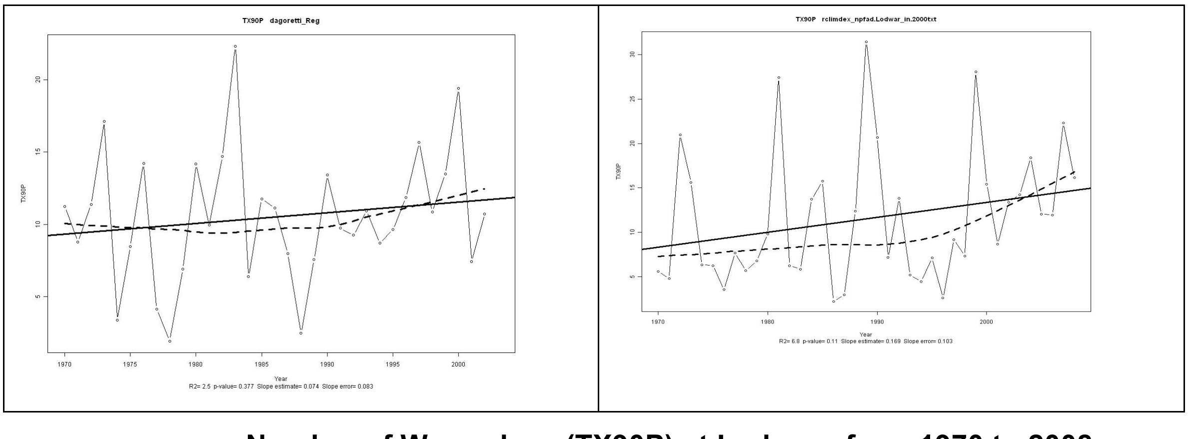
Figure below PRCPTOT – Observed vs PRECIS model: Dagoreti



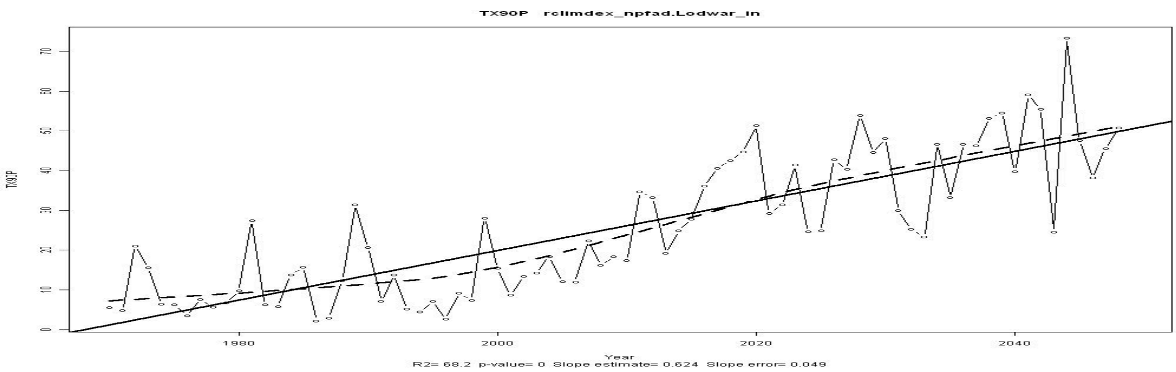
Total Annual Precipitation observed at Dagoreti from 1970 to 2008:
left panel is actual observations, while right panel is PRCPTOT from Rclimdex



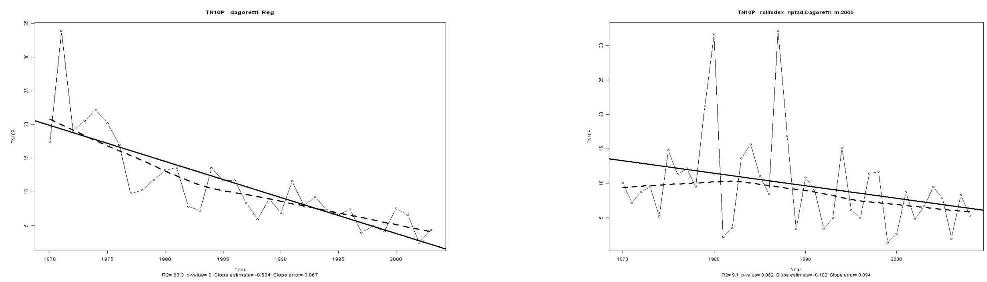
Total Annual Precipitation from PRECIS at Dagoreti from 1970 to 2050:



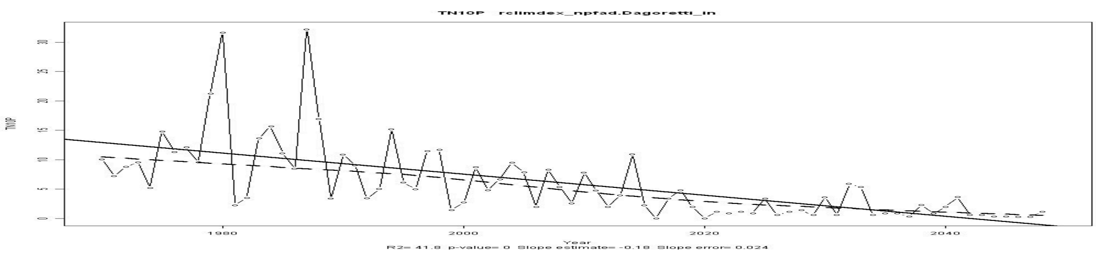
Number of Warm days (TX90P) at Lodwear from 1970 to 2008:
Left panel from observations; right panle from PRECIS model



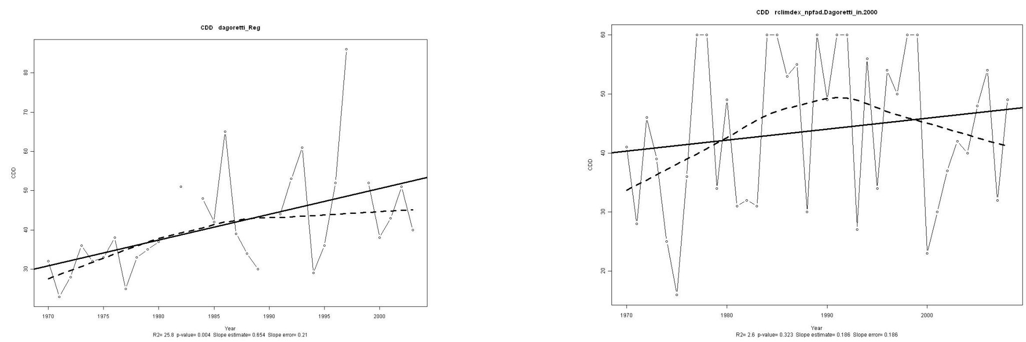
Number of Warm Days (TX90P) at Lodwear from PRECIS from 1970 to 2050



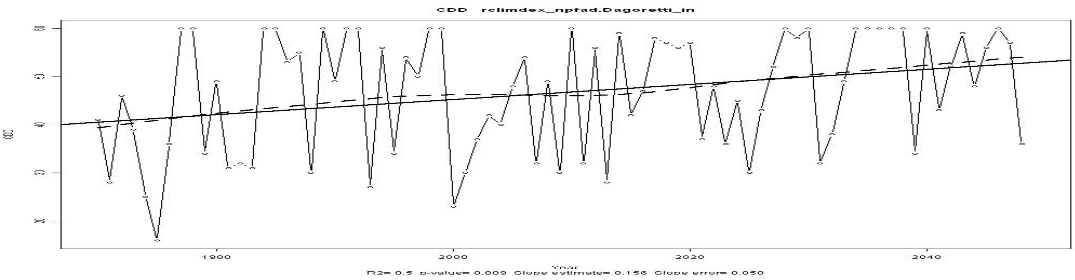
Number of Warm Nights (TN90P) Observed at Dagoreti from 1970 to 2008



Number of Warm Nights (TN90P) from PRECIS at Dagoreti from 1970 to 2050



Consecutive Dry Days (CDD) Observed at Dagoreti from 1970 to 2008



Consecutive Dry Days (CDD) from PRECIS at Dagoreti from 1970 to 2050

3. Uganda

The Ugandan report was a joint effort between by Dr Deus Bamanya Uganda Meteorological Department and Dr. Everline Komutunga, National Agricultural Research Organization (NARO).

Introduction

Uganda is a developing country with a population of approximately 25 million. Over 80% of the population lives in rural areas where agriculture is the major contributor to their livelihoods (UPHC, 2002). The agricultural activities are largely rain fed, making this sector heavily dependent on the onset and duration of seasonal rainfall. Over 80% of natural disasters in Uganda are related to extreme weather and climate events such as strong winds, severe thunderstorms, droughts and floods among others. These extreme weather and climate events affect the entire economy of the country.

Mr. Bamanya presented an oral summary at WS3 and showed graphic photos of the extreme events in Uganda that included floods, droughts, hailstorms, mudslides, strong winds, and lightning. The climate changes being experienced in Uganda include a decreasing number of cool nights and cool days, while annual total wet-day precipitation is increasing with more extremely wet days, though results were subject to serious gaps in data series or no data in some areas. He noted that the model did pick the direction of change and could be used for policy. Within Uganda, he saw the limitations being the limited awareness of climate impacts, lack of measurement of impacts and the difficulty in mainstreamed climate change.

Among the lessons learned were the needs for more analyses and more relevant regional indices, insufficient availability of data, the need for additional skills at national level, and the desirability of downscaling additional models to the national level. The main limitations to implementing climate information for adaptation and mitigation include the difficulty of mainstreaming climate understanding and information in sectoral policies, limited awareness within the country, lack of coordination within Uganda, and need to demonstrate the value of adapting to the impacts of climate change.

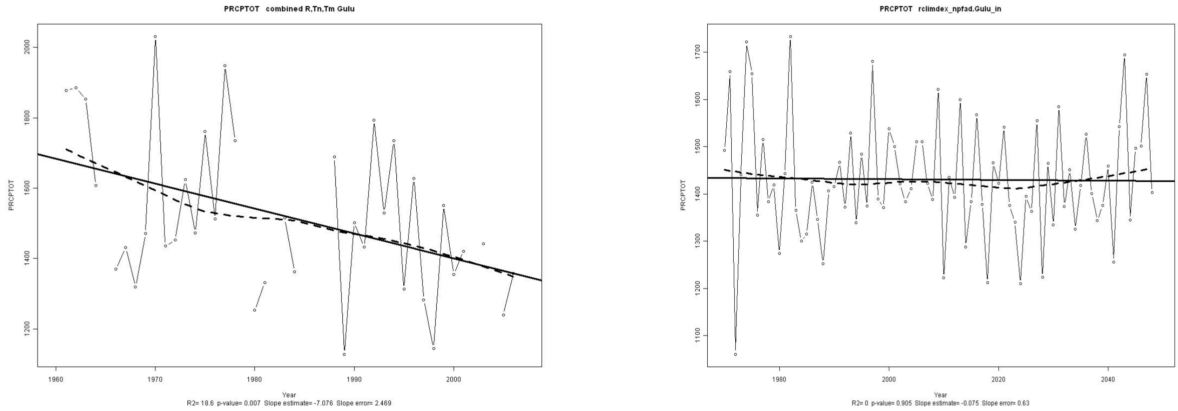
Data and Methodology

Uganda took the standard approach to its analyses that used:

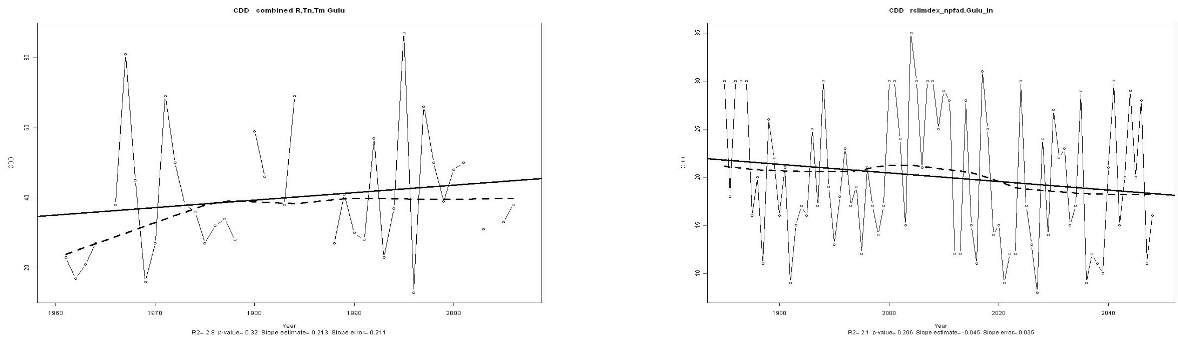
- Statistical analysis software for quality control and testing for homogeneity, prior to use in Rclimdex
- Rclimdex to calculate climate indices and to analyze trend in the regional models.
- PRECIS model to downscale GCM projections to regional scale for climate change impact studies. PRECIS output was then used in the Rclimdex to generate indices to compare with those from the national data;
- Trend analysis tool kit to analyze the significance of the trends.
- Arcview GIS software for effective visualization of results.

The training on climate data management, quality control, homogeneity procedures and the use of metadata were considered, trend and modeling skills (PRECIS, GIS, Rclimdex, and Trends) was all used in the analyses.

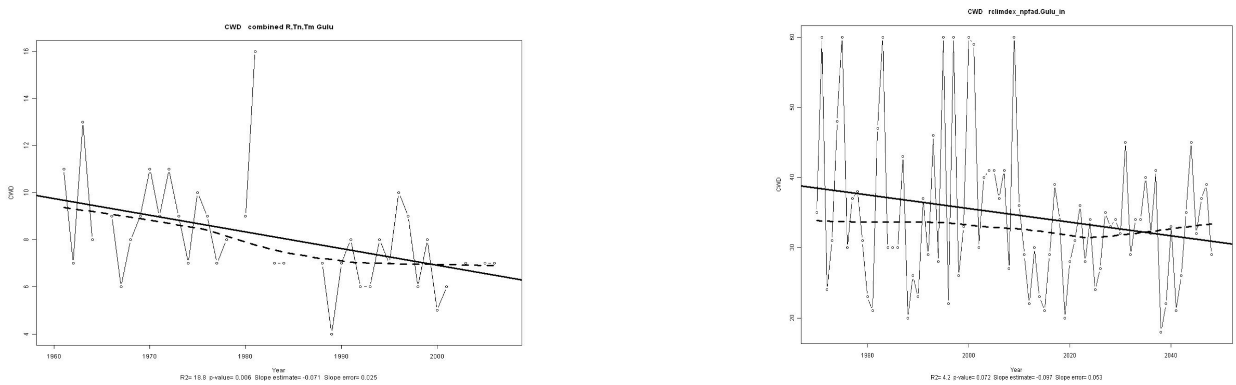
Results by Station in Uganda



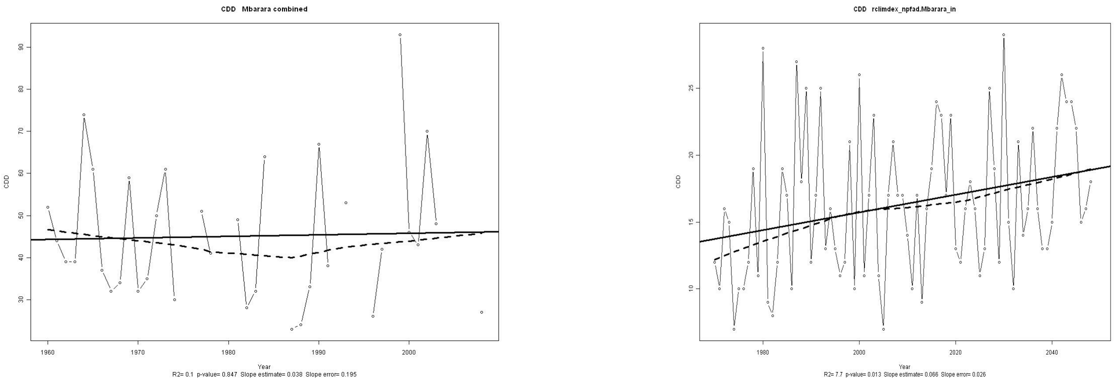
Total Annual Precipitation at GULU:
left panel – observed from 1960 to 2008; right panel – PRECIS from 1970 to 2050



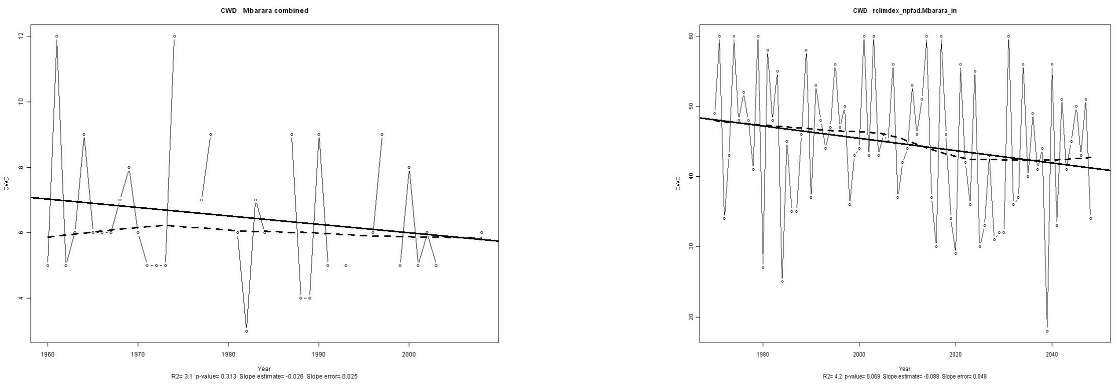
Consecutive Dry Days at Gulu
left panel – observed from 1960 to 2008; right panel – PRECIS from 1970 to 2050



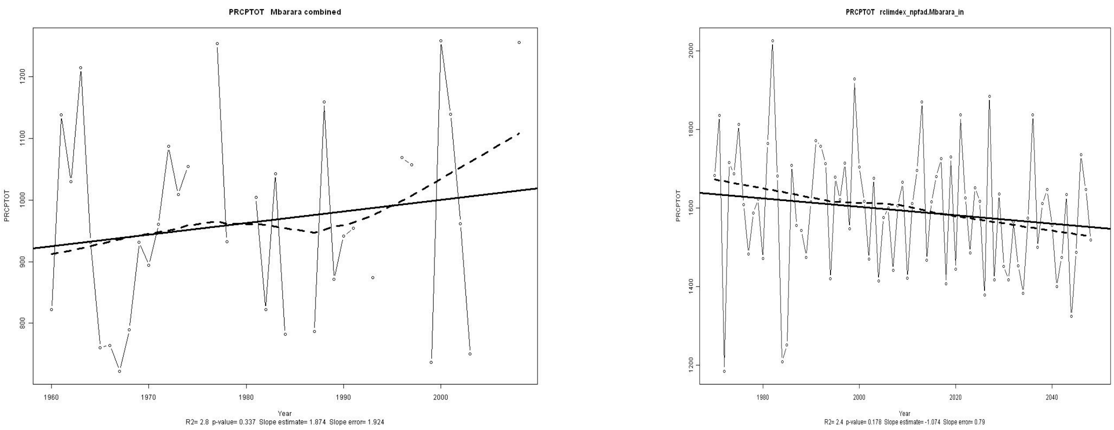
Consecutive Wet Days at Gulu
left panel – observed from 1960 to 2008; right panel – PRECIS from 1970 to 2050



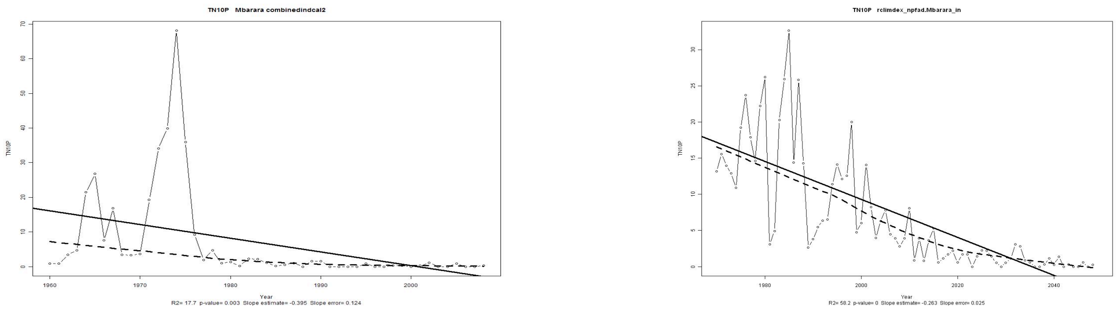
Consecutive Dry Days at Mbarara
left panel – observed from 1960 to 2008; right panel – PRECIS from 1970 to 2050



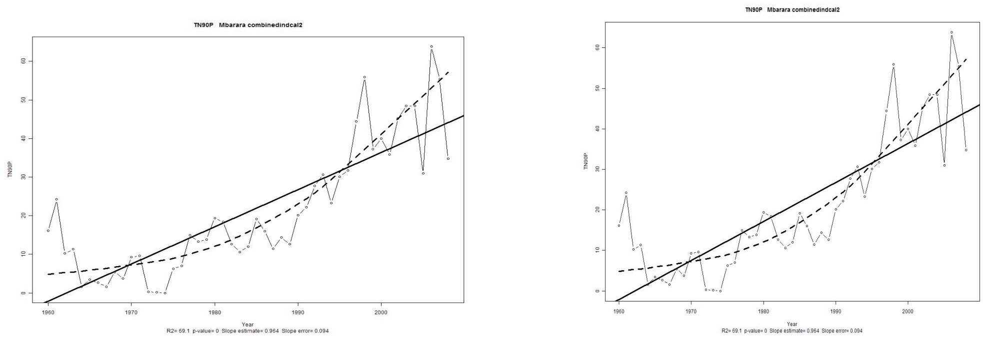
Consecutive Wet Days at Mbarara:
left panel – observed from 1960 to 2008; right panel – PRECIS from 1970 to 2050



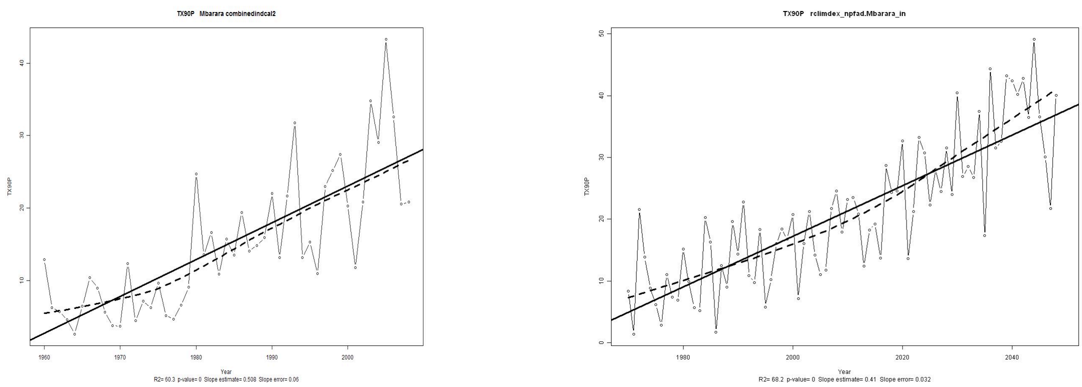
Total Annual Precipitation at Mbarara:
left panel – observed from 1960 to 2008; right panel – PRECIS from 1970 to 2050



Number of cool nights (TN10p) at Mbarara
left panel – observed from 1960 to 2008; right panel – PRECIS from 1970 to 2050



Number of warm nights (TN90p) at Mbarara
left panel – observed from 1960 to 2008; right panel – PRECIS from 1970 to 2050



Number of warm days (TX90p) at Mbarara
left panel – observed from 1960 to 2008; right panel – PRECIS from 1970 to 2050

4. Rwanda

This report was jointly prepared by Jean Baptiste Uwizeyimana and Anthony Twahirwa.

Introduction

Rwanda is a land locked country located in the southern hemisphere between latitude 1^0-3^0S and longitude 28^0-31^0E. The economy of the country depends mainly on rain-fed agriculture with 87% of the population dependent on agriculture. The country experiences two main rainy seasons March-May for the long rains and September-December for the short rains. The rainfall in the area is influenced by the penetration of Congo Air mass into the country, the inter-tropical convergence zone (ITCZ), local circulations and teleconnections from global Sea Surface Temperature (SSTs).

Rwanda is faced by significant limitations due to the lack of awareness and capacity nationally on climate variability and change, to the need for funding for Early Warning systems, and to a lack of adequate data which will require the rescuing of data and the establishment of new stations. Rwanda wants to build more partnerships for multidisciplinary work on climate, to develop the capacity to run regional models for climate applications and to develop its national climate services.

Data and methodology

The daily rainfall data and maximum and minimum temperature data were obtained from the National Meteorological Service of Rwanda. The daily records for 1971-2010 periods were available from 7 rainfall stations and 5 stations for temperature across Rwanda. Approximately 25% of the records had gaps with 2 stations having temperature data starting only in 1990.

Rwanda took the standard approach to its analyses that used:

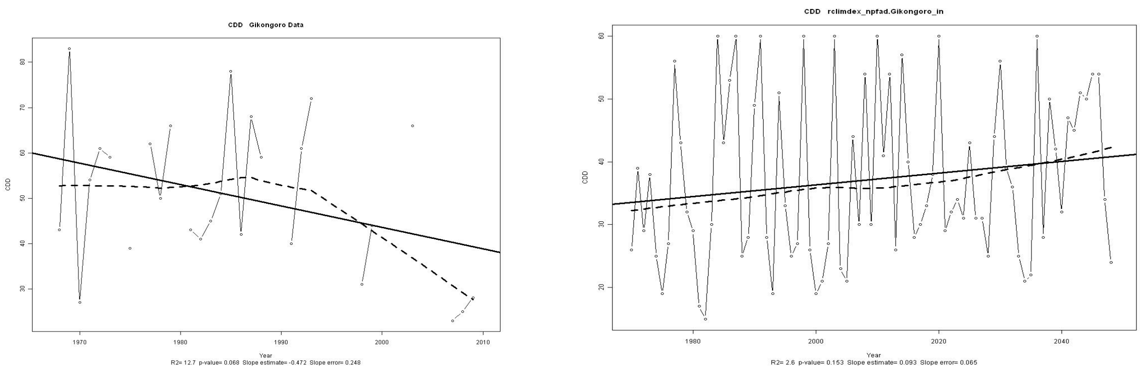
- Statistical analysis software for quality control and testing for homogeneity, prior to use in Rclimdex
- Rclimdex to calculate climate indices and to analyze trend in the regional models.
- PRECIS model to downscale GCM projections to regional scale for climate change impact studies. PRECIS output was then used in the Rclimdex to generate indices to compare with those from the national data;
- Trend analysis tool kit to analyze the significance of the trends.
- Arcview GIS software for effective visualization of results.

Conclusions

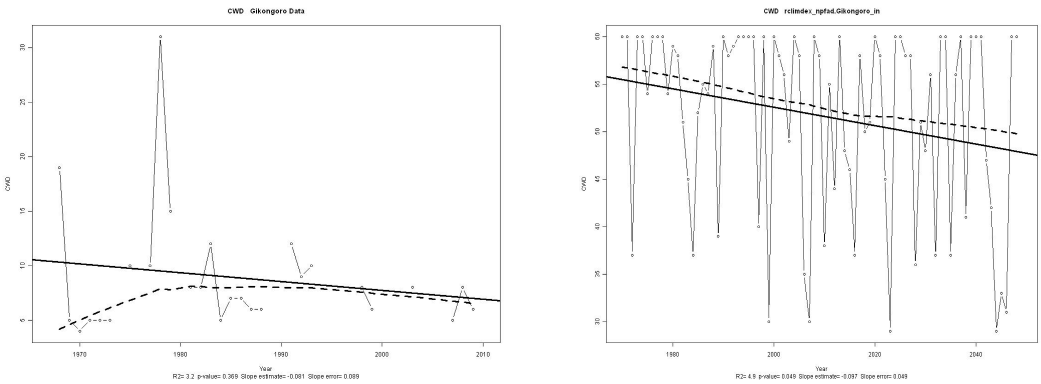
Time series data from three stations (Kigali, Kamembe, and Gikongoro) were analyzed. These time series showed evidence of changing climate conditions, including increasing trends in temperature and decreasing trends in rainfall. Results show a general decrease of rainfall for both observation and PRECIS model, while observations show a decreasing trend in CDD and an increasing trend for the PRECIS model. CWD shows a decreasing trend for both observation and PRECIS model for Gikongoro. The PRECIS model output mirrored the trend for temperature and rainfall, but there is a caveat on the results due to the need to include more stations and reanalysis data in these analyses.

The following abbreviations were used in the analyses - CCD – Consecutive Dry Days; CWD – Consecutive Wet Days; Total Rainfall – PRCPTOT

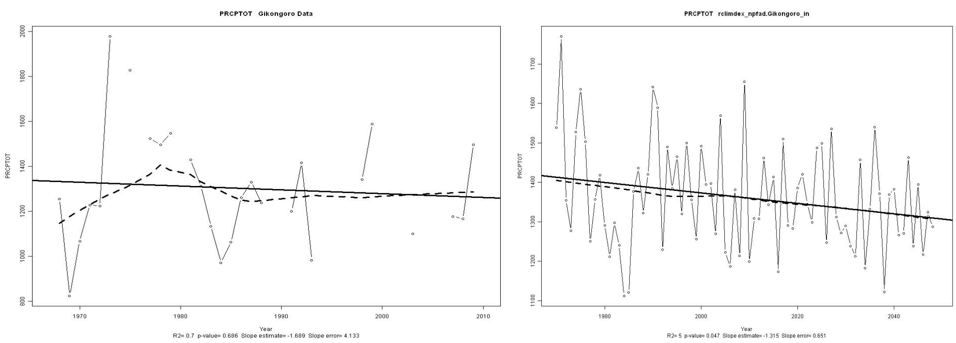
Results for 3 Rwandan stations



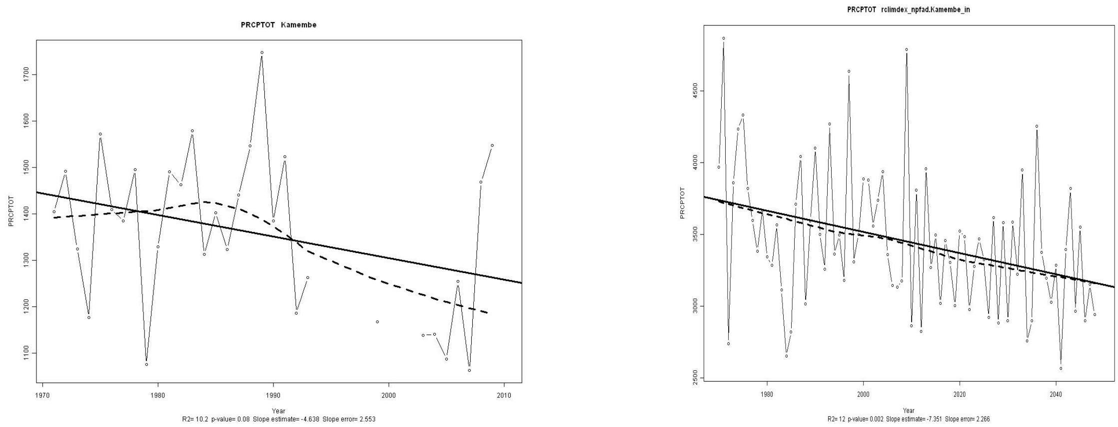
Consecutive Dry Days (CDD) at Gikongoro
left panel – observed from 1968 to 2009; right panel – PRECIS from 1970 to 2050



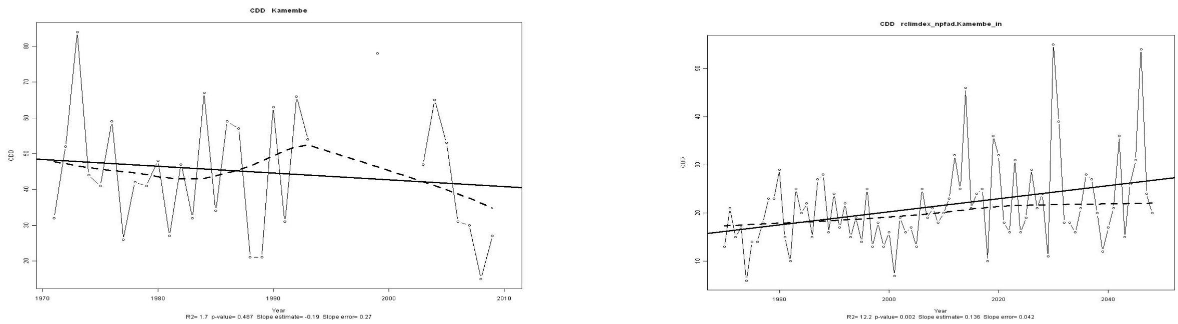
Consecutive Wet Days (CWD) at Gikongoro
left panel – observed from 1968 to 2009; right panel – PRECIS from 1970 to 2050



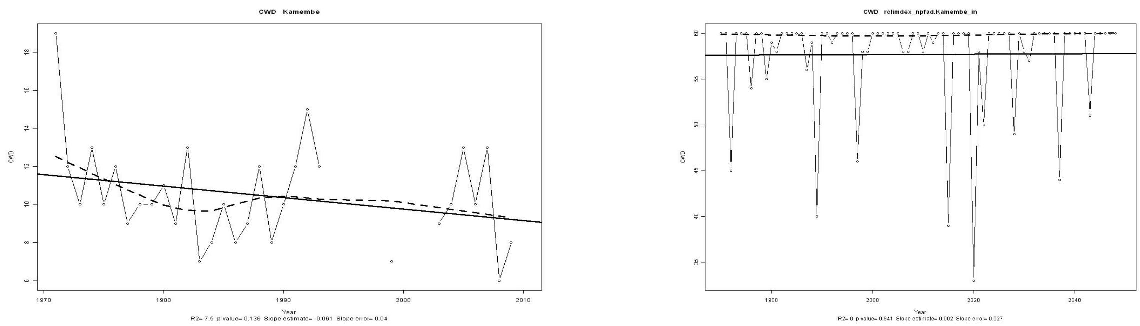
Total Annual Precipitation at Gikongoro:
left panel – observed from 1968 to 2009; right panel – PRECIS from 1970 to 2050



Total Annual Precipitation at Kamembe:
left panel – observed from 1968 to 2009; right panel – PRECIS from 1970 to 2050



Consecutive Dry Days (CDD) at Kamembe:
left panel – observed from 1968 to 2009; right panel – PRECIS from 1970 to 2050



Consecutive Wet Days (CWD) at Kamembe
left panel – observed from 1968 to 2009; right panel – PRECIS from 1970 to 2050

5. Burundi

Presented by Ruben Barakiza, Burundi National Meteorological Service

Introduction

The Burundi has 6 stations, but only 2 were included in their analyses. From WS2, the need to fill in gaps in data was clearly evident.

Mr. Barakiza noted that climate changes can manifest themselves quickly with negative impacts. Among the lessons learned were the need for monitoring extreme events, importance of multidisciplinary partnerships among data, models and users, the usefulness of GIS techniques, and the importance of continuing efforts and training on the analysis techniques from this project.

He concluded that Burundi would need additional capacity building, more coordination between DRR and CCA, better land use practices, and the development of early warning systems. He also stated that Burundi would need stronger involvement in regional (e.g., IGAD) and international organizations and better links with UNFCCC parties on climate change matters.

Methodology

Burundi took the standard approach to its analyses that used:

- Statistical analysis software for quality control and testing for homogeneity, prior to use in Rclimdex
- Rclimdex to calculate climate indices and to analyze trend in the regional models.
- PRECIS model to downscale GCM projections to regional scale for climate change impact studies. PRECIS output was then used in the Rclimdex to generate indices to compare with those from the national data;
- Trend analysis tool kit to analyze the significance of the trends.
- Arcview GIS software for effective visualization of results.

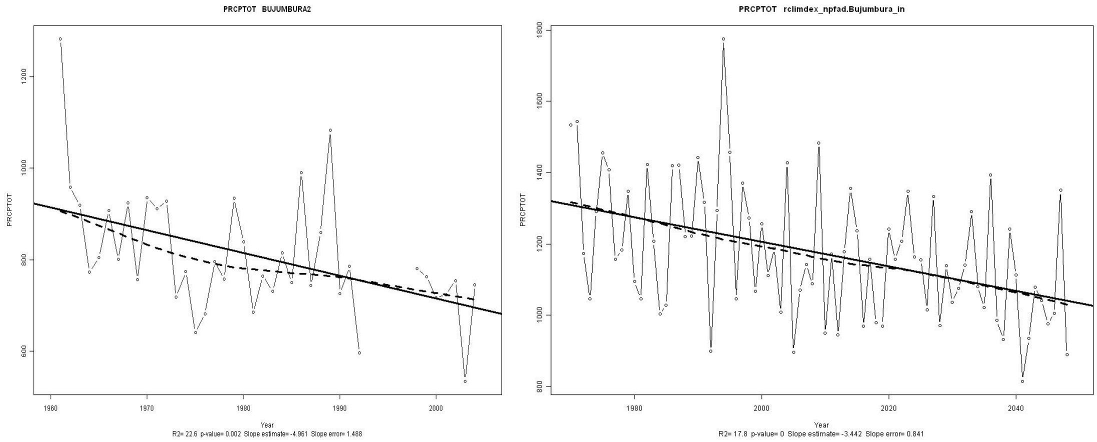
The intent of Burundi with limited data was still to use the data available to assess the observed climate variability and change and to evaluate the skill of regional models for the country. The activities at the workshops demonstrated the value of the collaborative use of data and standardized climate indices, including those representing extremes, among countries in the region. The quality control software and homogeneity tests allowed them to identify erroneous data in rainfall and temperature and also to test the consistency of the data. Due to the gaps in their data, they used the Excel Pivot Table technique and RCLIMDEX 1.0 software to fill in gaps.

Conclusions

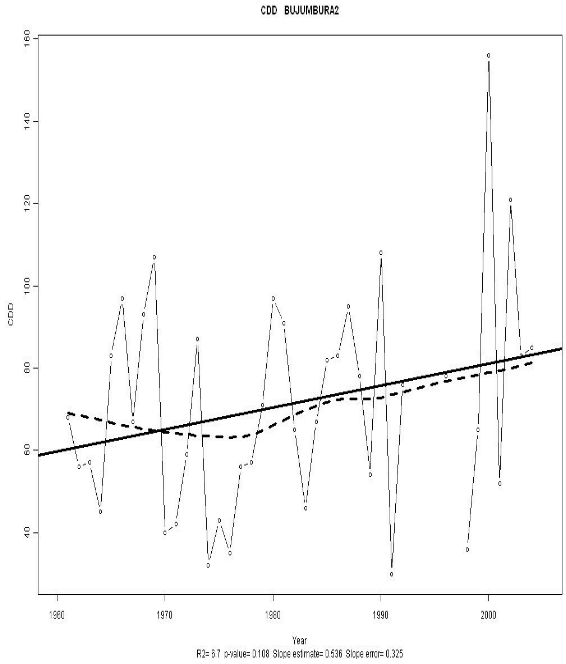
The Burundi representative noted that the overall comparison between Rclimdex and PRECIS showed good agreement with a decreasing trend for total precipitation (PRCPTOT). There is a significant decreasing trend in annual total precipitation days with a rain rate >1mm at the two stations: Bujumbura and Muyinga. The decrease seems to be greater at Bujumbura in western Burundi than at Muyinga in the east.

The number of the days, where the minimum temperature is greater than 20 ºC (TX90p), has been increasing since the 1970's in both Rclimdex and PRECIS model output as has the value of daily minimum temperature (TX10p) in the Rclimdex and PRECIS models.

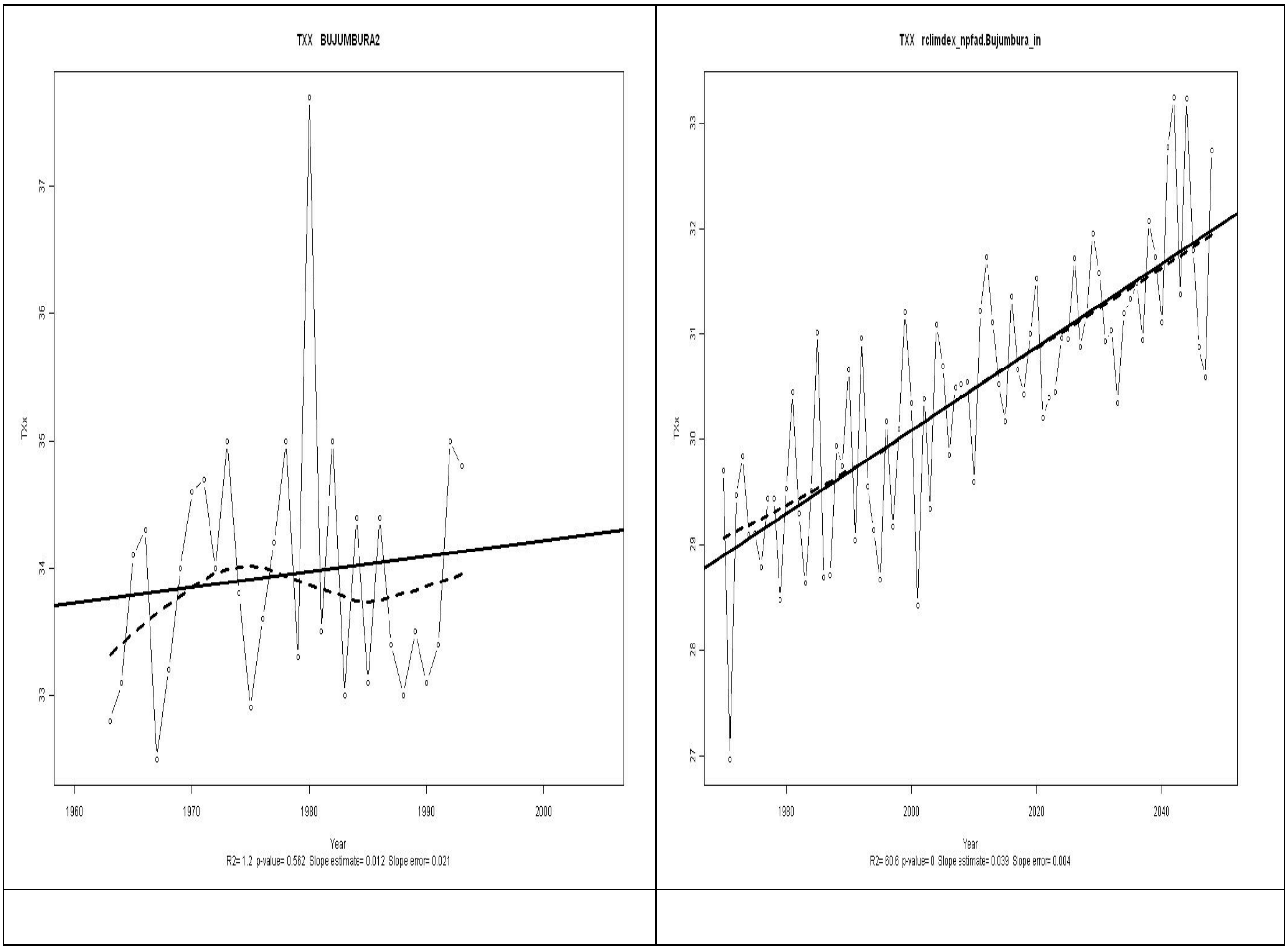
Results from Stations



Total Annual Precipitation at Bujumbura:
left panel – observed from 1968 to 2009; right panel – PRECIS from 1970 to 2050



Consecutive Dry Days (CDD) observed at Bujumbura from 1968 to 2009



Monthly maximum value for the daily maximum temperature (TXx) for Bujumbura left panel – observed from 1962 to 1985; right panel – PRECIS from 1970 to 2050

6. Tanzania

The report was prepared by Habiba Mtongori and Carol Kilembe

Introduction

Tanzania reviewed the extreme events that affect the country (e.g., floods, drought, coastal eosin, etc.) and noted the significant impacts from changing climate conditions, such as the retreat of the Kilimanjaro glacier and the decline in seasonal rainfall amounts with the increased risk of more dry spells of at least 7 days within certain regions of Tanzania. An additional concerns are the rise in sea level leading to salt water intrusion affecting crop yields, (e.g., for cassava), erosion of beaches and damage to coastal infrastructure. Tanzania is undertaking adaptation actions particularly related to agriculture and livestock and is faced with the need for capacity building, e.g. technology transfer in implementing some of the adaptation/mitigation measures, and limitations on funding to implement such strategies.

Methodology

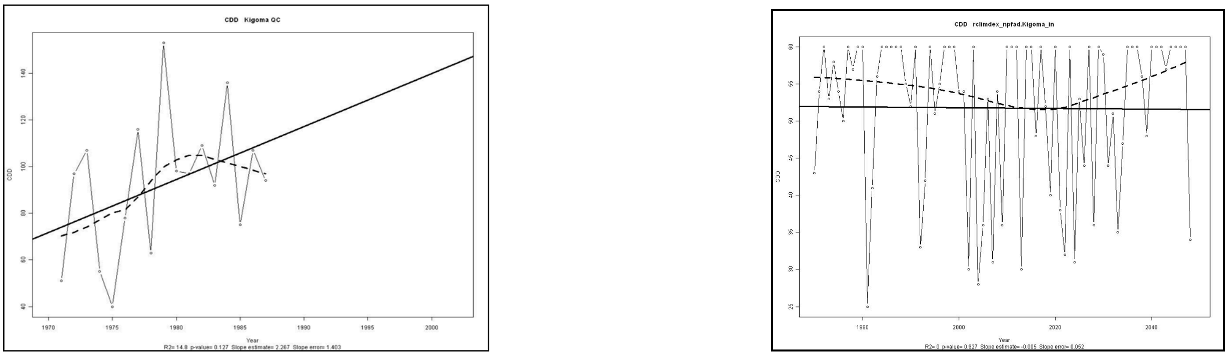
Tanzania took the standard approach to its analyses in using:

- Statistical analysis software for quality control and testing for homogeneity, prior to use in Rclimdex
- Rclimdex to calculate climate indices and to analyze trend in the regional models.
- PRECIS model to downscale GCM projections to regional scale for climate change impact studies. PRECIS output was then used in the Rclimdex to generate indices to compare with those from the national data;
- Trend analysis tool kit to analyze the significance of the trends.
- Arcview GIS software for effective visualization of results.

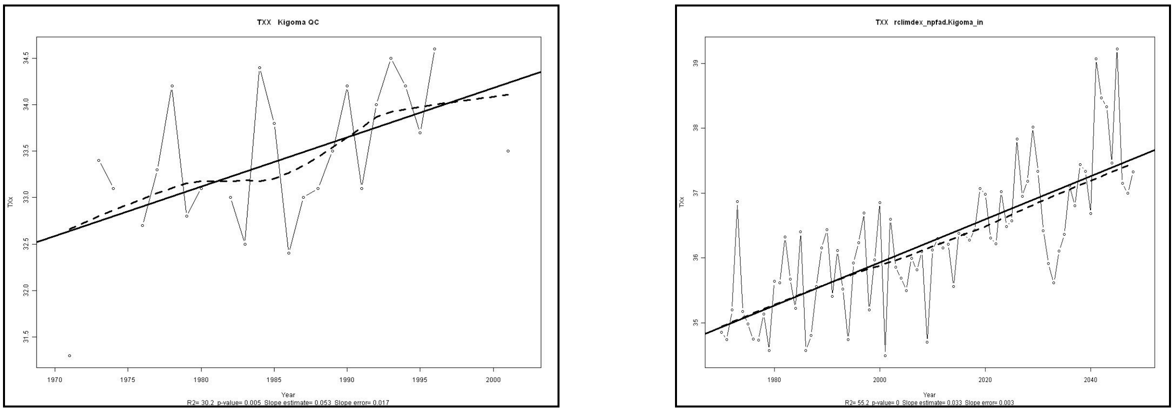
The trend analysis focused on selected climatic indices, including the number of cool nights (TN10P), the number of warm days (TX90P), Consecutive Dry Days (CDD), and the annual total wet-day precipitation (PRCPTOT) for Tanzania.

There was agreement between data and PRECIS model that the trend in number of consecutive dry days was increasing more rapidly in western Tanzania than in the east.

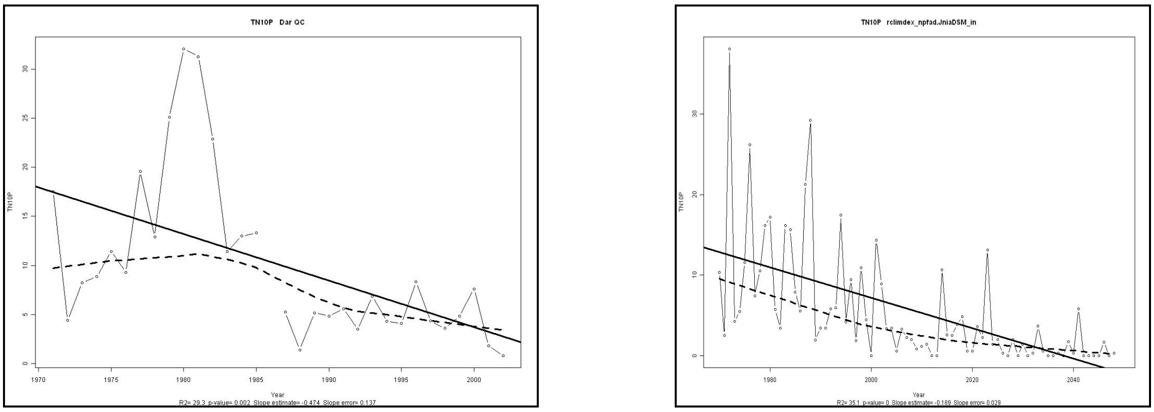
Results



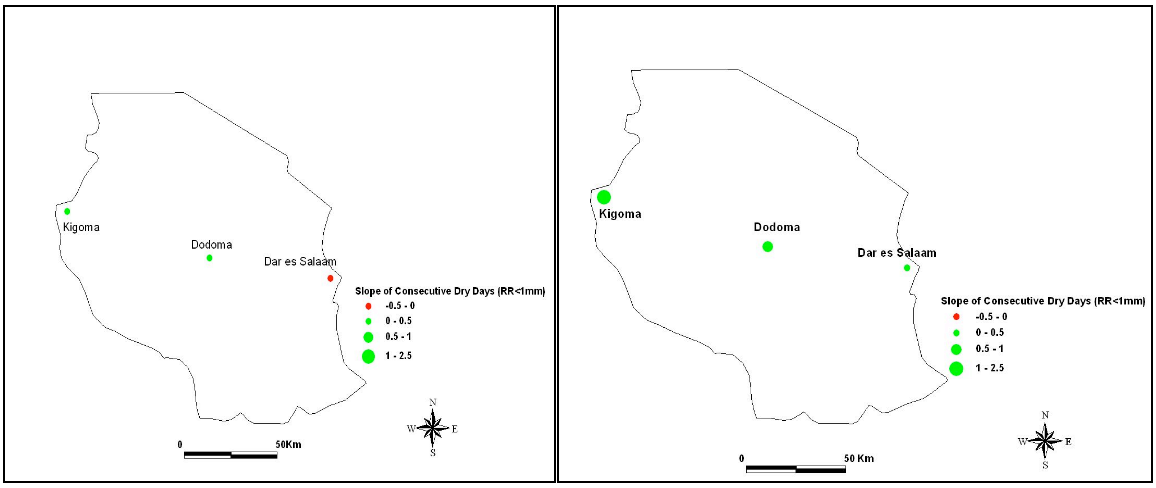
Consecutive Dry Days (CDD) at Kigoma:
left panel – observed from 1972 to 1987; right panel – PRECIS from 1970 to 2050



Monthly maximum value for the daily maximum temperature (TXx) for Kigoma
left panel – observed from 1973 to 1987; right panel – PRECIS from 1970 to 2050



Number of cool nights (TN10p) at Dar es Salaam
left panel – observed from 1972 to 2003; right panel – PRECIS from 1970 to 2050



GIS Visualization of the slope of Consecutive Dry Days (CDD) at 3 stations in Tanzania
left panel from observations; right panel from PRECIS

7. Eritrea

Prepared by Isaac Fesseha,

Eritrea is an arid to semi-arid country. Long term observations indicate its vulnerability to many extreme climatic events, such as droughts; floods or heavy rains; landslides and erosion, heat waves, and strong wind, dust and sand storms with low visibility. For example, although annual rainfall is low (<20 centimeters per year), some areas may get up to 40 centimeters within a day or two and that heat and cold waves may exceed 45^{o}C and reach -5^{o}C respectively.

Finally Mr. Fesseha noted that policy makers in Eritrea should take actions to mitigate and adapt to climate change through mechanisms such as irrigation, aforestation, and reducing anthropogenic pollution and needed to prepare proficient emergency plans and incorporate them in their strategic plan.

Methodology

Eritrea has limited data and did not provide plots of indices due to the lack of time series. The Eritrean participants benefitted from the skills gained from the exercises on using Rclimdex, Arcview, TRENDS, although there was not enough time for practicing the new techniques. More workshops of the type of implemented in this project are needed to build capacity. Eritrea has a need for new software and funding for implementing all aspects of climate change adaptation.

Results

Eritrea, although not providing plots of indices due to the lack of time series, did cite its vulnerability to many extreme events. Examples are given below:

- Data on droughts from Asmara show well below average precipitation in many years.

1969	198mm/ year	(38%)	1991	179mm/year	(34%)
1989	177mm/year	(34%)	2008	298mm/year	(57%)
1990	215mm/year	(41%)			

- In contrast, Asmara reported in July 2001, 124mm of rain in 3:50 minutes time and in August 2001, 143mm of rain in 3:30 minutes, causing blockage in drainage systems, cars floating and crashing, and dams and buildings destroyed. Landslides resulting from heavy rains are a common phenomenon in Eritrea particularly in roads and villages constructed over escarpments and they regularly interrupt land transportation.

- During 2007 a number of dams were destroyed or eroded away due to heavy rains. Tessenei recorded 109mm on 9 July and Agordat recorded 113mm on 10July.

- Floods and strong intense precipitation with records from Massawa showing:

1953 (November)	113 mm	1964 (January)	130 mm
1961 (February)	127 mm	1975 (December)	346 mm of heavy rain over over 2 days
1994 (October)	heavy rain, associated with strong wind but amount not recorded. This caused great loss in life and structural damage.		

- Eritrea gets periods on very high temperatures with Massawa reporting a maximum of 48.4 C in July 2004, 47.0 C in June 2004, and 47.0 C in July 2005. Further in Assab maximum temperatures were reported of 49.2 C in August 1997= 45.0 C in June1997= 44.0 C in July 2001, and 45.0 C in July 2003. People were collapsing and becoming unconscious, so that they could not perform their jobs properly. In contrast, Asmara reported low temperatures of -5.4 C in December 1984, -6.5 C in January 1989, and -4.3 C in December 2004 affecting agriculture.

8. Ethiopia

Presented by Mr. Ato Mitiku Kassa

Introduction

Ethiopia like other GHA countries suffers from droughts, floods, increasing temperatures, and failure of the rainy season (e.g., in MAM and OND rainfall). Among the lessons learned are the need for improved identification and coordination of national adaptation and mitigation projects, for improved bench marking of best practices and use of allocated budgets, and for more awareness and understanding of climate and changing conditions. In implementing climate adaptation actions, Ethiopia is limited by lack of funding, dedicated coordinating body, national commitment to adapting to climate change and the capacity to carry out detailed investigations of climate impacts, vulnerabilities, and adaptation measures

Methodology and Software

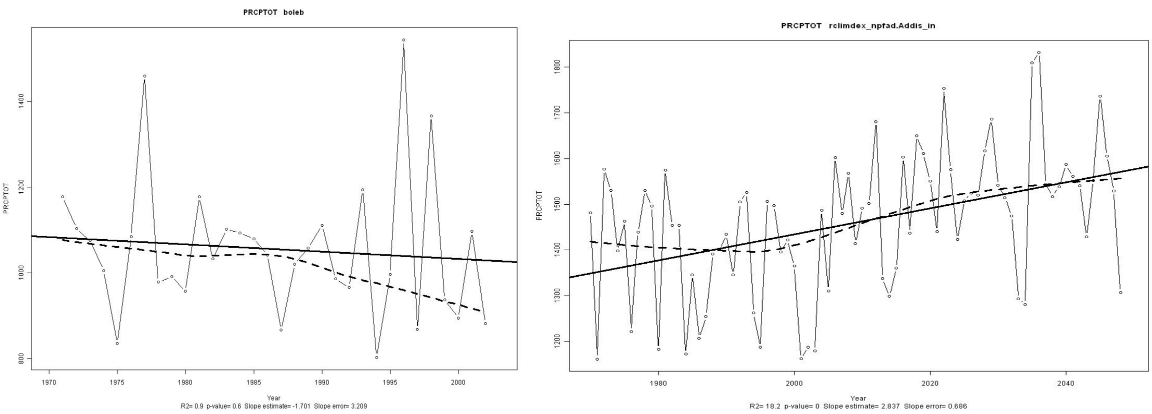
Ethiopia took the standard approach to its analyses by using:

- Statistical analysis software for quality control and testing for homogeneity, prior to use in Rclimdex
- Rclimdex to calculate climate indices and to analyze trend in the regional models.
- PRECIS model to downscale GCM projections to regional scale for climate change impact studies. PRECIS output was then used in the Rclimdex to generate indices to compare with those from the national data;
- Trend analysis tool kit to analyze the significance of the trends.
- Arcview GIS software for effective visualization of results.

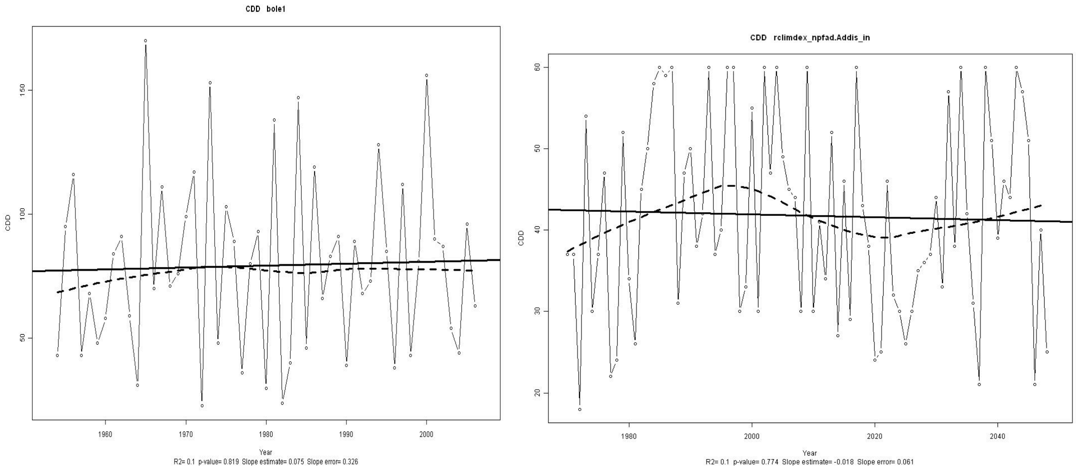
The Ethiopian participants cited the benefits from the training in use of the Rclimdex indices and the different analysis methods such as TREND, Arcview, and the PRECIS model.

For its report Ethiopia selected 3 of the 16 Ethiopian stations at Addis Ababa Bole, Awassa, and Gondar, and for each station, four indices – total annual precipitation (PRCEPTOT), number of warm days when the daytime temperature is greater than the 90th percentile (TX90p), number of cold nights when the nighttime temperature if less than the 10^{th} percentile (TN10p), and the number of consecutive dry days (CDD) – were prepared.

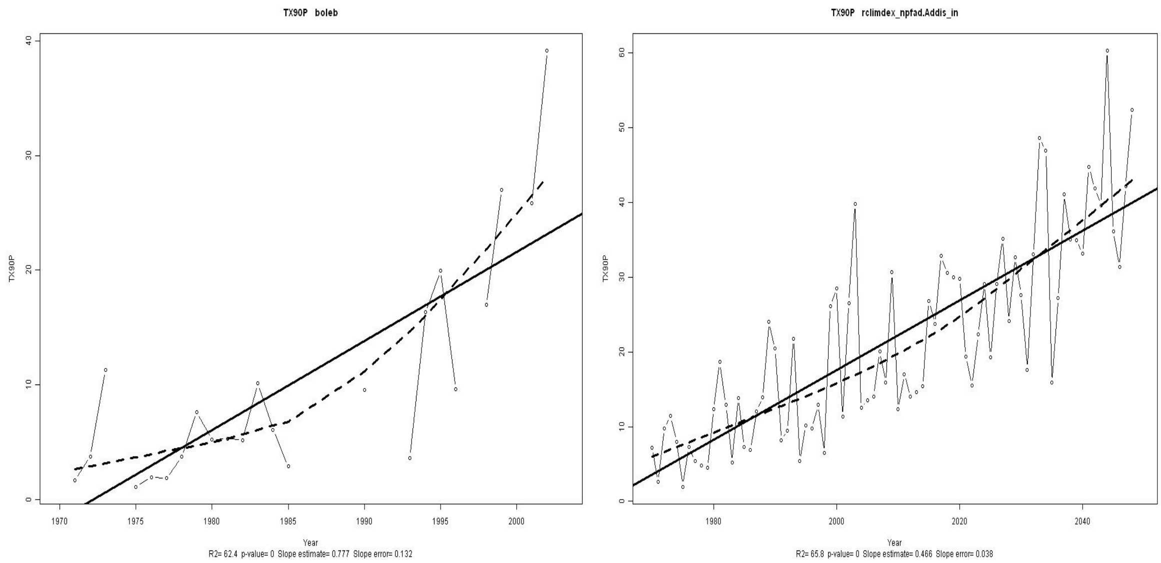
Results by Station



Total Annual Precipitation at Addis Ababa Bole:
left panel – observed from 1968 to 2009; right panel – PRECIS from 1970 to 2050



Consecutive Dry Days (CDD) at Addis Ababa Bole:
left panel – observed from 1968 to 2009; right panel – PRECIS from 1970 to 2050



Number of warm days (TX90p) at Addis Ababa Bole:
left panel – observed from 1960 to 2008; right panel – PRECIS from 1970 to 2050

Conclusions

The trend in daytime temperatures (TX90P) was increasing for all stations. Other indices showed an increase at some stations and a decrease at others.

9. Djibouti

Presented by Mr. Abdoulrahman Youssouf Nour, Djibouti Meteorological Service

The Republic of Djibouti – well known as Red-Sea Republic – is located in the Greater Horn of Africa and bounded by latitude 10.5°S - 12°.7 S and longitude 42.0°E43.5°E. It is situated at the gateway to the Red Sea, bordering Eritrea, Ethiopia and Somalia. Djibouti has an area of 23 000 km2 and a population of one million people with 65% living in the coastal zone. The north and southeastern parts of the country are suitable for agriculture, while in the other areas, the population is semi-nomad and practice agro-pastoral activities.

Evidences of climate change in Djibouti include increasing frequencies of extreme events, increasing number of warm days, decreasing number of cool days, and the potential for sea level rise leading to salt water intrusion. Ongoing adaptation activities in Djibouti include desalinization of sea water, development of fish farming, and cooperative projects with neighboring countries (e.g., electrical connections to Ethiopian hydro-power, renting of crop land). The issues to be addressed include enhancing in-country collaboration among institutions, integrating climate change in planned programs, need for additional funding (e.g., for NMS activities) and better technology.

Methodology

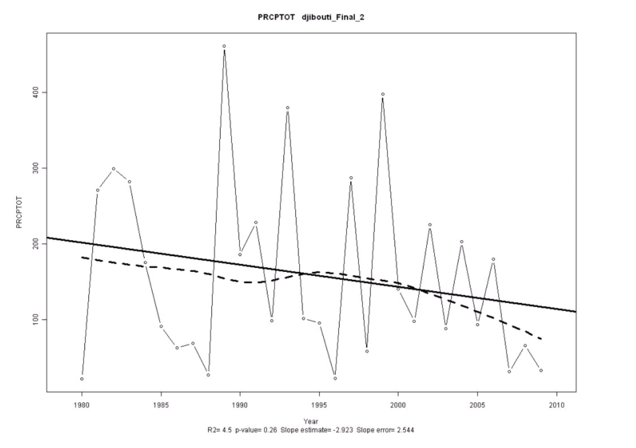
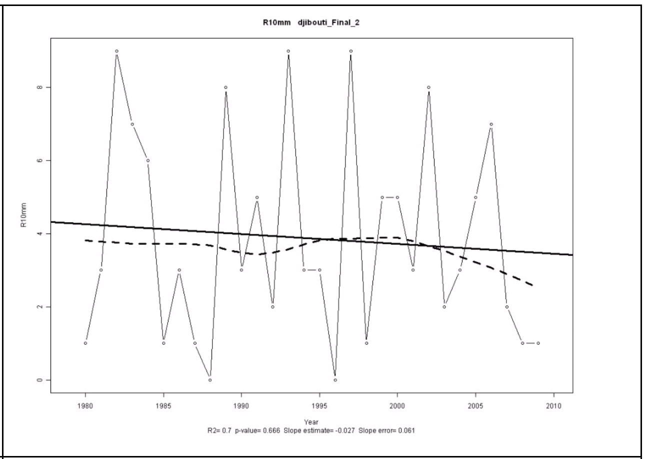
Djibouti has 5 climatic zones with 1 meteorological station located at Djibouti in its coastal zone. This station provides good quality, daily data with less than 1% of missing data. Djibouti took the standard approach to its analyses by using:

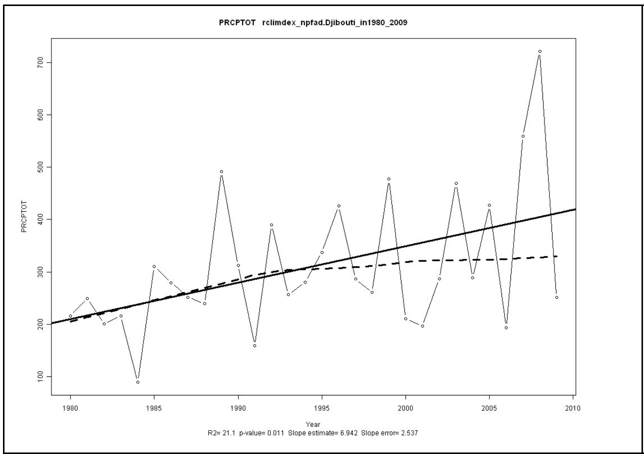
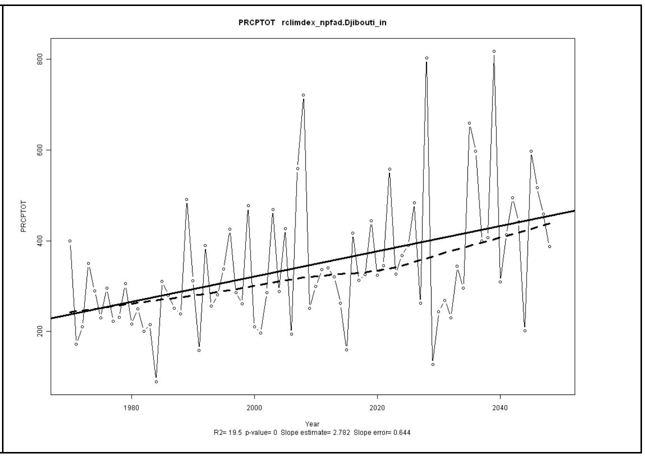
- Statistical analysis software for quality control and testing for homogeneity, prior to use in Rclimdex
- Rclimdex to calculate climate indices and to analyze trend in the regional models.
- PRECIS model to downscale GCM projections to regional scale for climate change impact studies. PRECIS output was then used in the Rclimdex to generate indices to compare with those from the national data;
- Trend analysis tool kit to analyze the significance of the trends.
- Arcview GIS software for effective visualization of results.

Conclusions

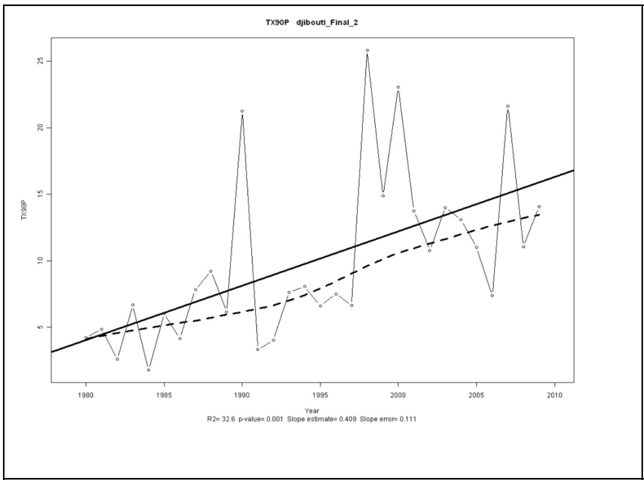
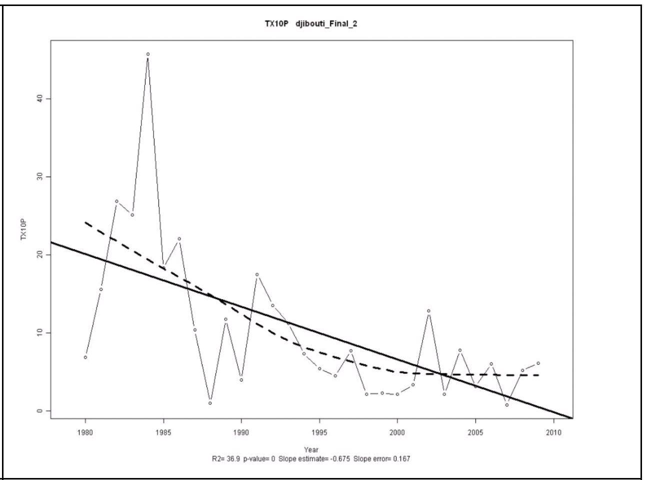
From the analyses below, Mr. Nour concluded that the PRECIS model captured most of the temperature trends but projections for rainfall were limited with no projection for sea level change. He noted the difficulty in quantifying uncertainties at this stage and the need to use other models. The analysis showed evidence of climate change in the increasing frequencies of extreme events, increasing number of warm days with a decreasing number of cool days. The main issue was if the sea level rises, Djibouti risks salt water intrusion into its coastal zone.

Results for the one station at Djibouti

	
Total Annual Precipitation (PRCPTOT) From 1960 to 2009	**Number of Days with Precipitation > 10mm from 1980 to 2009**

Total Annual Precipitation at Djibouti:
left panel – observed from 1980 to 2009; right panel – PRECIS from 1970 to 2050

	
Number of Warm Days (TX90p) from 1980-2009	**Number of Cool Days (TX10p) from 1980 to 2009**

10. Somalia

Somalia has a population estimated to be 8 to 10 million and covers 367,000 sq. km. It generally has an arid to semi-arid climate with two rainy seasons and large spatial and temporal variability. Rainfall, produced from the moist air from the Indian Ocean, is the defining climatic characteristic and is variable from season to season and within the season.

The Somalia land area is desert or semi-desert with approximately 60 percent of savannah woodlands, primarily used as rangeland and as the local source of fuel. Only about 13 % of the land, primarily in southern Somalia can be cultivated but is not farmed on a regular basis. The livelihood of Somalis comes from agriculture, as agro-pastoralists or pastoralist (nomads), and from urban pursuits. Like most developing countries, Somalia is prone to frequent climate related disasters mainly droughts and floods.

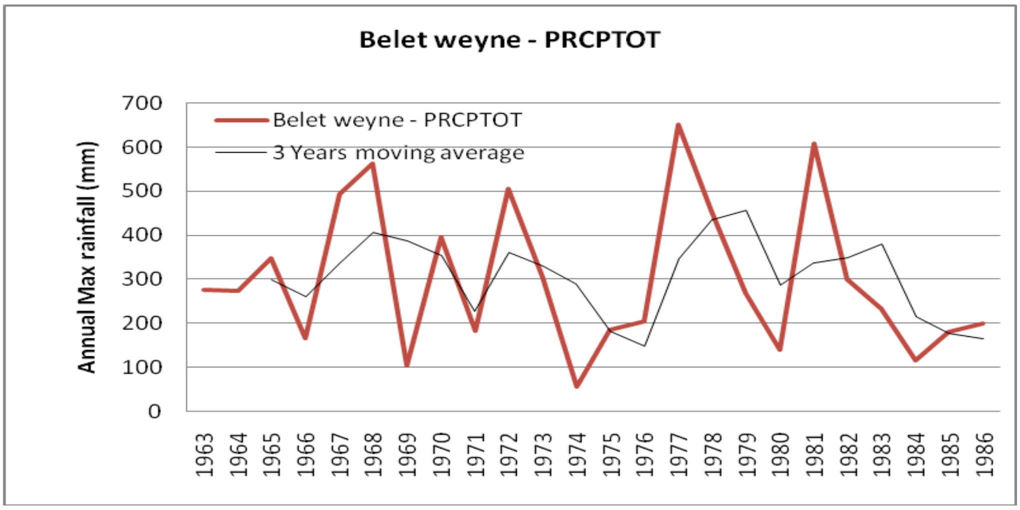
The social and economic well-being of the Somali people is intrinsically linked to the status of the country's natural resources. Many of the rules for governing the use and protection of natural resources have not been enforced since the government collapsed in the early nineties.

The challenges faced by Somalia both politically and climatically include determining future trends due to changing climate conditions and the impact of these changes on the ecosystem and the wider environment and the adequacy of the environment's carrying capacity to sustain human lives. Recent history has lead to significant displacement of people from one place to another because of the civil war and economic disruptions.

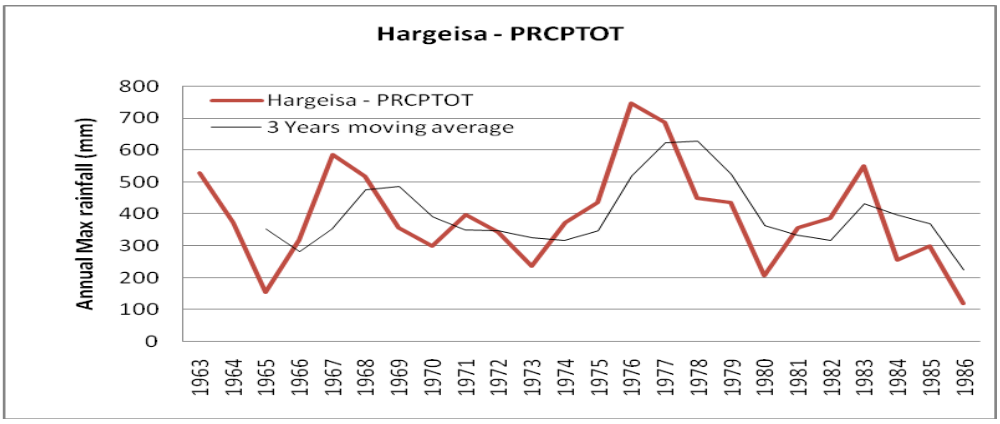
The Somalia report is in two parts: analyses of selected quality-controlled indices for three stations -- Hargeisa, Mogadishu, and Belet Weyne from 1961 to 1990 and after 1990, comparative, episodic information on significant events.

- Selected climate indices from 1960 to 1988

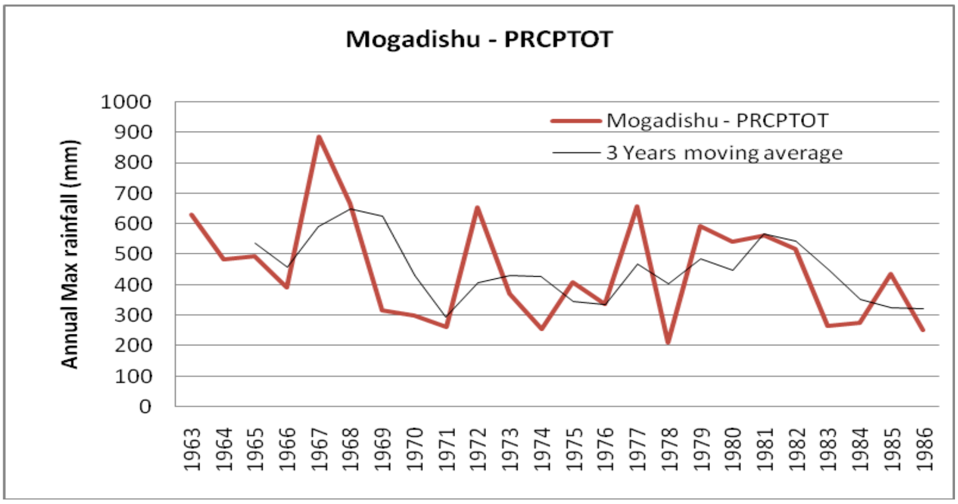
During Workshop 1, daily rainfall data from the three 3 stations -- Hargeisa, Mogadishu, and Belet Weyne -- were analyzed for the seven precipitation indices, since there was no temperature data available from Somalia.



Total Annual Precipitation observed at Belet weyne from 1963 to 1986



Total Annual Precipitation observed at Hargeisa from 1963 to 1986



Total Annual Precipitation at Mogadishu from 1963 to 1986

The Figures above show a minor decreasing trend in PRCPTOT at Hargeisa, while both Belet Weyne and Mogadishu show a decreasing trend. The participants recommended that rainfall estimation techniques (RFEs) be adopted for the missing stations and that Rclimdex software be adopted for seasonal analysis as well.

- **Comparative, episodic information on significant events after 1990**

Despite the lack of data, the Somalis were able to supply qualitative precipitation amounts in various regions, including:

Average precipitation:	
South around Kismayo to Ras Kambion	about 600 mm per year,
Western side around Baidoa	400-500 mm per year,
Around Mogadishu	400-500 mm per year,
Central regions around Galkaio	300 mm per year,
North east around Bosaso and along the coast of Gulf of Aden	< 250 mm per year,
Northwest around Hargeisa	about 500mm per year.

Appendix 1: List of ETCCDI core Climate Indices

ID	Indicator name	Definitions	UNITS
FD0	Frost days	Annual count when TN(daily minimum)<0ºC	Days
SU25	Summer days	Annual count when TX(daily maximum)>25ºC	Days
ID0	Ice days	Annual count when TX(daily maximum)<0ºC	Days
TR20	Tropical nights	Annual count when TN(daily minimum)>20ºC	Days
GSL	Growing season Length	Annual (1st Jan to 31st Dec in NH, 1st July to 30th June in SH) count between first span of at least 6 days with TG>5ºC and first span after July 1 (January 1 in SH) of 6 days with TG<5ºC	Days
TXx	Max Tmax	Monthly maximum value of daily maximum temp	ºC
TNx	Max Tmin	Monthly maximum value of daily minimum temp	ºC
TXn	Min Tmax	Monthly minimum value of daily maximum temp	ºC
TNn	Min Tmin	Monthly minimum value of daily minimum temp	ºC
TN10p	Cool nights	Percentage of days when TN<10th percentile	Days
TX10p	Cool days	Percentage of days when TX<10th percentile	Days
TN90p	Warm nights	Percentage of days when TN>90th percentile	Days
TX90p	Warm days	Percentage of days when TX>90th percentile	Days
WSDI	Warm spell duration indicator	Annual count of days with at least 6 consecutive days when TX>90th percentile	Days
CSDI	Cold spell duration indicator	Annual count of days with at least 6 consecutive days when TN<10th percentile	Days
DTR	Diurnal temperature range	Monthly mean difference between TX and TN	ºC
RX1day	Max 1-day precipitation amount	Monthly maximum 1-day precipitation	Mm
Rx5day	Max 5-day precipitation amount	Monthly maximum consecutive 5-day precipitation	Mm
SDII	Simple daily intensity index	Annual total precipitation divided by the number of wet days (defined as PRCP ≥ 1.0mm) in the year	Mm/day
R10	Number of heavy precipitation days	Annual count of days when PRCP ≥ 10mm	Days
R20	Number of very heavy precipitation days	Annual count of days when PRCP ≥ 20mm	Days
Rnn	Number of days above nn mm	Annual count of days when PRCP ≥ nn mm, nn is user defined threshold	Days
CDD	Consecutive dry days	Maximum number of consecutive days with RR<1mm	Days

CWD	Consecutive wet days	Maximum number of consecutive days with RR ≥ 1mm	Days
R95p	Very wet days	Annual total PRCP when RR>95th percentile	Mm
R99p	Extremely wet days	Annual total PRCP when RR>99th percentile	mm
PRCPTOT	Annual total wet-day precipitation	Annual total PRCP in wet days (RR ≥ 1mm)	mm

Source: RClimDex (1.0) User Manual By Xuebin Zhang and Feng Yang, Climate Research Branch, Environment Canada, Downsview, Ontario, Canada.

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